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# AN ASSESSMENT OF THE FLEXIBLE PACKAGING SYSTEM FOR HEAT-PROCESSED FOODS

by

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Packaging Division



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13. ABSTRACT


The objective of this report was to document the significant results which were part of a critical evaluation of data accumulated during the exploratory development of a flexible packaging system for heat-processed foods. The basic period covered was from calendar years 1959 through 1970.

All aspects of the technical effort were divided into eight sections in the report, namely, materials, package design, bacterial penetration, processing, tests and procedures, shipment and storage, consumer handling, and production capability. Each section contains a brief analysis of pertinent facts and data followed by a concluding statement. These conclusions are consolidated in the summary.

The data show that adequate information exists or is actively being pursued to provide assurance for the use of heat-processed foods in flexible packages by the Military.


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## FOREWORD

The work covered by this report was performed under Project 1J66208D552, Packaging Exploratory Development, Task 02 -- Design of Flexible Packaging Systems. The overall project program is to provide operational rations which satisfy the changing tactical and logistical requirements of the Military. Currently, a requirement exists in the Combat Development Objectives Guide, paragraph 1412b(1), specifying radical improvements in packaging. Exploratory development conducted under this task has produced the flexible package for thermoprocessed foods. This flexible package is a proposed replacement for the rigid, hermetically sealed, metal food container. It is basic to the development of a family of lightweight, nonrigid packages for ready-to-eat heat-processed foods.

U. S. Army Natick Laboratories established a work unit under Task 02 -- Design of Flexible Packaging Systems -- to be certain that all essential aspects in the flexible package development were adequately considered and resolved or placed under active investigation. A thorough review was made of related data in NLABS literature -- in-house, laboratory notebooks and files, contract reports -- and industry activities. This report is part of the effort to assure that there were no omissions in major technical areas during its entire development history. Presented briefly are the results from a critical evaluation of the data accumulated since conception.

The U. S. Army Natick Laboratories Project Officer is Dr. Edward A. Nebesky, Director of the General Equipment & Packaging Laboratory, and the Task Officer is Mr. Frank J. Rubinate, Chief of the Packaging Division, General Equipment & Packaging Laboratory.

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All aspects of the technical effort were divided into eight sections in the report, namely, materials, package design, bacterial penetration, processing, tests and procedures, shipment and storage, consumer handling, and production capability. Each section contains a brief analysis of pertinent facts and data followed by a concluding statement. These conclusions are consolidated in the summary.

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# AN ASSESSMENT OF

# THE FLEXIBLE PACKAGING SYSTEM FOR HEAT-PROCESSED FOODS

## INTRODUCTION

The development of a flexible packaging system for heat-processed foods has been underway in the General Equipment & Packaging Laboratory, U. S. Army Natick Laboratories, since 1959. It is a new application of the flexible package that should not be confused with *boil-in-bag* packages. The *boil-in-bag* system is limited to frozen foods with high temperature exposure, 212°F., applied at the end of the life of the package and its contents, i.e., at the consumer's level. The package for *heat-processed foods* contains shelf-stable foods which have been subjected to sterilizing temperatures as high as 250°F. and pressure fluctuations common to thermal processing glass and metal containers in a retort prior to shipment, storage, and consumption by the consumer. Since it is commercially sterile in the consumer's hands, any failure of the heat-processed package at any point in its lifetime can create a health hazard. The flexible package, therefore, is required to equal the performance of its predecessors for shelf-stable foods. The past decade has been devoted to developing a packaging system to replace one container -- the tin-plated steel can -- which was developed about a century ago. The current high level of sophistication in the areas of science, engineering, technology, and industrial know-how has made this new development possible. The program is in the final stages of development, with an estimated completion date in the fall of 1972.

Good management dictates that periodic review of the development objectives be exercised relative to need, validity of effort, and success potential. This has been done at frequent intervals. Because of the complexity of the system, the time, manpower, and funds invested, it is appropriate at this point to make a critical assessment of all aspects of the technical effort to assure that all that must be done has been accomplished, or will be accomplished, prior to completion of the program. This report covers the results of such an assessment. While the review covers primarily the development efforts of the General Equipment & Packaging Laboratory, USANLABS, both in-house and under contract, it also includes available information developed by industry, universities, and other government agencies. It is important to note that the following assessment is related to adequacy of the flexible package for military use.

For convenience, the [illegible] al effort was divided into the following sections:

1. Materials
2. Package Design
3. Bacterial Penetration
4. Processing
5. Tests and Procedures
6. Shipment and Storage
7. Consumer Handling
8. Production Capability

## RESULTS OF ASSESSMENT

1. Materials.

During the course of development, more than two hundred materials were evaluated. It was established that the materials for this application would be required to possess the following properties:

a. Resistance to sterilization temperatures of either steam, water, or steam-air mixtures.

b. Sufficient impermeability to gas and moisture to provide an acceptable product when stored for a minimum of six months at 100°F. and two years at 70°F.

c. Sufficient mechanical strength to maintain a hermetic seal and commercial sterility standards during the shelf-life of the package.

d. Basic prerequisites of meeting the Food and Drug Administration Regulations pertaining to composition, usage, and extractability.

As the first step in the evaluation studies, sheets of candidate materials were placed in the retort to determine whether they would stand high temperatures without delamination or degradation. Materials that passed this test were then formed into pouches approximately

4-1/2 by 7 inches each, filled with five ounces of a meat product, evacuated and sealed, and then put through a complete processing cycle in the retort (30 minutes at 250°F.). Promising materials were further test-packed with various products and stored under controlled conditions to establish their shelf-life potential. Plastic materials alone and in combination, with and without aluminum foil, were investigated.

Although the early materials evaluation data showed that many films can withstand retorting when used alone, single films were deficient in barrier properties, and adequate shelf-life was not possible.[1] Laminated materials containing foil offer much more in the way of shelf-life. Combinations of films such as Mylar-Saran-polyethylene* were thought to be an ideal packaging material by some investigators, yet storage life proved to be rather short.[2, 3, 4] Further improvement of the functional properties of the individual component films are needed if such laminates are to become excellent packaging materials. Some of the chemical and physical changes that occur in heat-processed foods as a function of the barrier properties of the flexible packaging material employed are described in the literature.[2, 3, 5] Based on overall performance, the material selected for military purposes consists of a three-ply lamination containing 0.5-mil polyester/ 0.35-mil aluminum foil/3-mil polyolefin (heat-sealable).

Delamination of the polyester during heat-processing was a difficult problem to cope with in early material investigations. Considerable variation in performance was experienced from one supplier to another and from one lot to another from the same supplier. The sporadic nature of the failure indicated that the trouble was in the laminating process. This difficulty was corrected with changes in production line operations by the major suppliers knowledgeable in this application. With proper application of adhesives, use of specific laminating techniques, and tightening of quality control, there is no good reason to expect delamination to be a problem. No delamination has been experienced in recent tests of materials intended for the application. Procedures for measurement of bond strength have also been developed and are being evaluated to assure an ability to distinguish between good and marginal bonding.[6]

In exploratory development under contract with the Massachusetts Institute of Technology, several potentially suited materials were tested for safety in regard to food additive

*Mylar: a product of E. I. Du Pont de Nemours & Co.
Saran: a product of Dow Chemical Company.

regulations. Extractability tests were conducted as prescribed in the Food and Drug Administration Regulations for heat-processing foods at 212°F. and 250°F.[7] In addition under contract, the Pillsbury Company did further work with select materials for heat-processing at 250°F. and above.[8] The results of these studies showed several of the polymeric food contacting materials to be safe from the standpoint of migration or leaching of material components into the food. Subsequently, three suppliers have certified their polyester/foil/polyolefin materials will meet the FDA's extractive requirements for this application.

From the above work two major conclusions can be drawn as far as the military application of this technique is concerned. They are:

a. Aluminum foil is an essential component of the packaging material.

b. Flexible materials are available that possess the essential properties for heat-processed foods.

2. Package Design.

The underlying objective in the design of the flexible package for heat-processed foods is to accomplish reductions in weight and space and to provide more convenience in carrying combat field rations. Appraisal of packaging procedures for components of field rations shows that considerable thought has already been given to lightweight flexible packages for nonprocessed components such as cocoa, candies, cereal, and other dry items. Heat-processed, high-moisture items such as meats and fruits, however, are still packaged in the conventional tinplate can. Before initiating development work, however, the researchers gave careful consideration to the advantages and disadvantages of the conventional tinplate can.[9] Weighed carefully were the following:

a. Advantages of the metal can:

(1) It provides a sealed container impervious to moisture, gas, and bacteria.

(2) It provides, with rare exception, a minimum two-year storage life for ration components now in the military supply system.

(3) It offers resistance to rough handling in shipment and exposure to climatic extremes when provided with an exterior corrosion-resistance camouflage coating.

(4) It is commercially available in specific sizes in sufficient volume to meet military demands.

(5) It is produced with universally available equipment for manufacture, filling, closing, and packing into shipping cases.

(6) It is subject to a tremendous volume of technical data upon which to base requirements for new food items.

(7) It is inexpensive.

b. Disadvantages of the metal can:

(1) It is heavy.

(2) Its cylindrical shape is wasteful of space and difficult to carry on the person.

(3) Its rigidity can result in injury to the soldier during combat.

(4) It is dependent on tin produced outside the United States.

(5) The current program of reduction in weight of tin-coating is approaching the point where the satisfactory shelf-life of two years minimum is questionable for certain items.

(6) The cost in modification of equipment to produce cans of new dimensions (either round or rectangular) is high.

(7) The military is restricted to sizes commercially available in procuring the large volume of food required for the Armed Forces.

(8) It is not disposable.

The total benefits to the Military that could be achieved by modifying the conventional can, as through the use of aluminum, were considered marginal. Aluminum cans on a gauge-for-gauge basis are significantly weaker than comparable tinplate cans.[10] Other types of containers were considered and discarded for numerous reasons.

Examples of such were:

a. Preformed plastics -- materials not adequate for retorting.

b. Tubes, plastic and metal -- limited to puree type items.

c. Composites -- seam closure characteristics poor, and materials not adequate for retorting.

d. Flat rectangular cans -- production insufficient (handling lines in plants set for round), reliability less than flexible package, slow closing, rigid.

After careful consideration of the above, and taking into account the rapid advances in the state of the art of material converting, it was determined that sufficient potential existed to develop a hermetically sealed flexible pouch. It was felt that a flexible pouch having many of the advantages of the can and few, if any, of its disadvantages was achievable.

The flexible package system which has been developed consists of a 4-1/2" by 7" pouch inserted and adhered to a fiberboard folder (see Figure 1). It is designed to fit the pockets of the soldier's field uniform (see Figure 2). The thickness of the filled pouch varies with the product from 1/2 inch to about 3/4 of an inch. Each pouch contains 4-1/2 to 5-1/2 ounces of food. It has a tear notch to facilitate opening. Permanent labeling, marking, and camouflage can be applied to the pouch for special purposes.

The folder provides puncture resistance, improves the resistance to rough handling, and is an integral part of the flexible package. The earliest package design consisted of the pouch with a fiberboard backing on one side and the four seals protected by a fiberboard picture frame arrangement on the other side. Another design was a double-pouch construction. After experimentation it was realized that the pouch required complete protection against mechanical damage, and finally the present fiberboard folder type of arrangement was selected. The folder was designed with a locking feature to permit easy opening for inspection purposes. In evaluating its performance, it was found that bonding the pouch to the folder provided four times better protection than just placing the pouch in the folder. In 1963, U. S. Department of Agriculture sanctioned the military use of the system with the proviso that the folder be used to inclose the pouch.

On the basis of all considerations, the current flexible package design is considered to be the best and closest to meeting the military needs. The adopted design represents a savings or reduction in container weight greater than 40% over tinplate cans. When used for the Meal, Ready-to-Eat, Individual, that is designed as a replacement for the Meal, Combat, Individual, savings in weight were measurable. In the new Meal, Ready-to-Eat, Individual (see

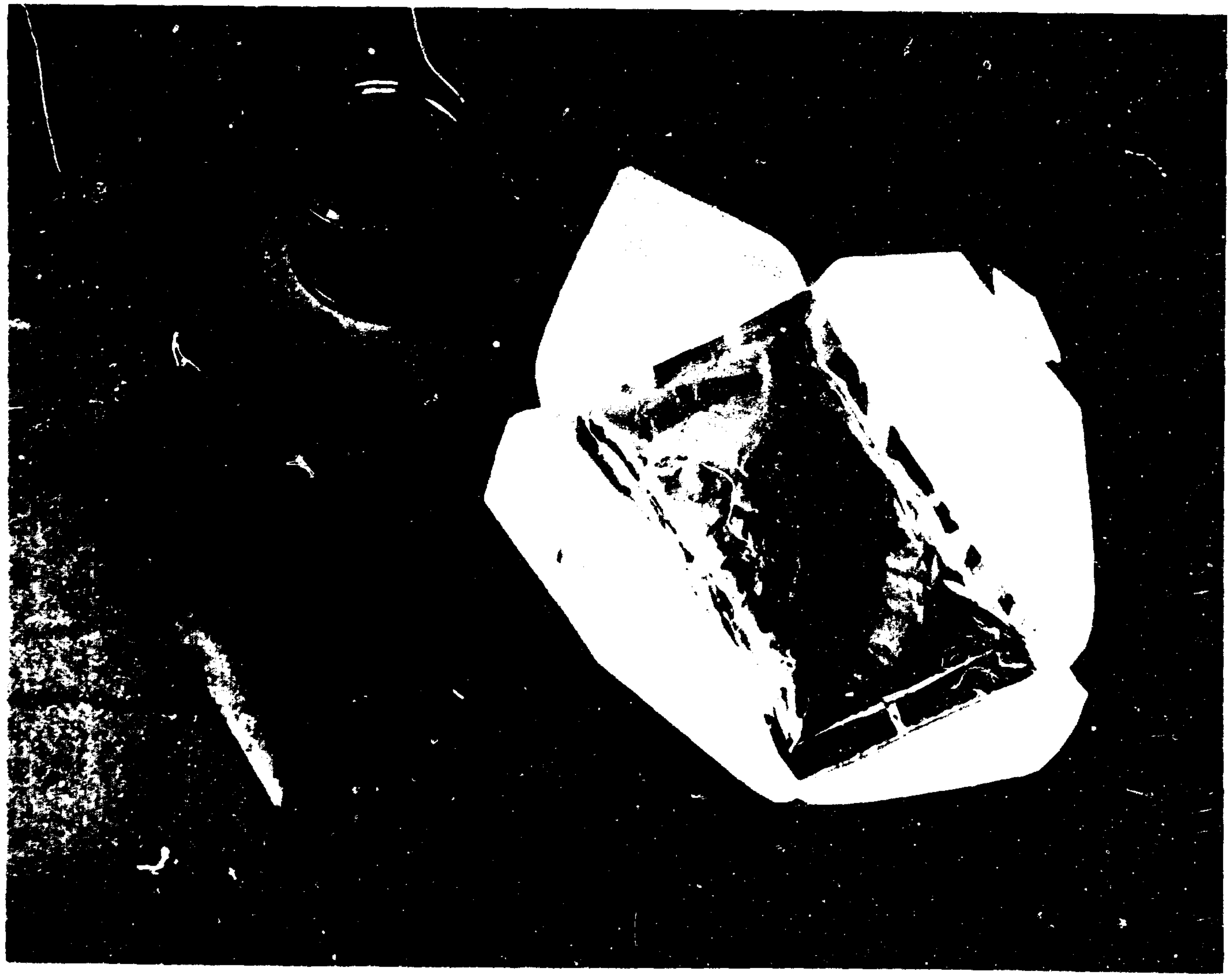

Figure 1. Flexible package showing construction (shown with metal can in field rations)

Figure 2. Soldier placing three flexible packages in upper pocket of field jacket.

Figure 3) a savings of 23% (5 pounds per case) was realized, indicating possible advantages from a logistical and user standpoint.[11]

3. Bacterial Penetration.

The integrity of flexible packages to penetration by bacteria is essential for preservation of heat- or irradiation-processed foods. Several researchers studying these methods of preservation have investigated the academic and practical points it brings to mind. Salient points of the investigations conducted follow.

Some very early work reported in 1958 to determine the bacterial resistance of flexible packages was conducted under a project for packaging radiation-sterilized foods. Under contract, MIT investigated the frequency of penetration by bacteria through flat sheets of a wide variety of flexible packaging materials (plain, creased, and heat-sealed) and of pouches made from the same.[12] The organisms used to evaluate the materials were Escherichia coli, Rhodotorula ruba, Serratia marcescens, Clostridium sporogenes, Monascus purpureus, and Fusarium culmorum.

In general, the results showed

a. Laminated foils are more resistant to penetration by microorganisms than plain foils.

b. Plain aluminum foils one mil or less in thickness showed penetration by microorganisms; whereas, plain unsupported films more than 0.5 mil in thickness did not show penetration.

c. Creasing tends to increase the frequency of penetration of films two mils or less. Polyethylene was impenetrable after creasing when a thickness of three mils was used.*

d. Heat-sealing does not have a significant effect on the frequency of penetration of most films more than 0.5 mil in thickness.

Further work under contract with FMC (Food Machinery Corporation) was connected with microbial agents E. coli and S. marcescens.[13] In this project the microbial penetration resistance of films, aluminum foil, and laminates of primary interest for the heat-processed food application was studied. Previous work gave the limits which were used in specifying materials for this study. Material tested ranged from 0.5- to 1.00-mil polyester, 0.35- to 0.70-mil aluminum foil, and 1.0- to 3.0-mil polypropylene and vinyl. The results showed that the

*Reference is made to the creasing procedure described in the Paper Trade Journal, 118, No. 2, p. 30. 1944.

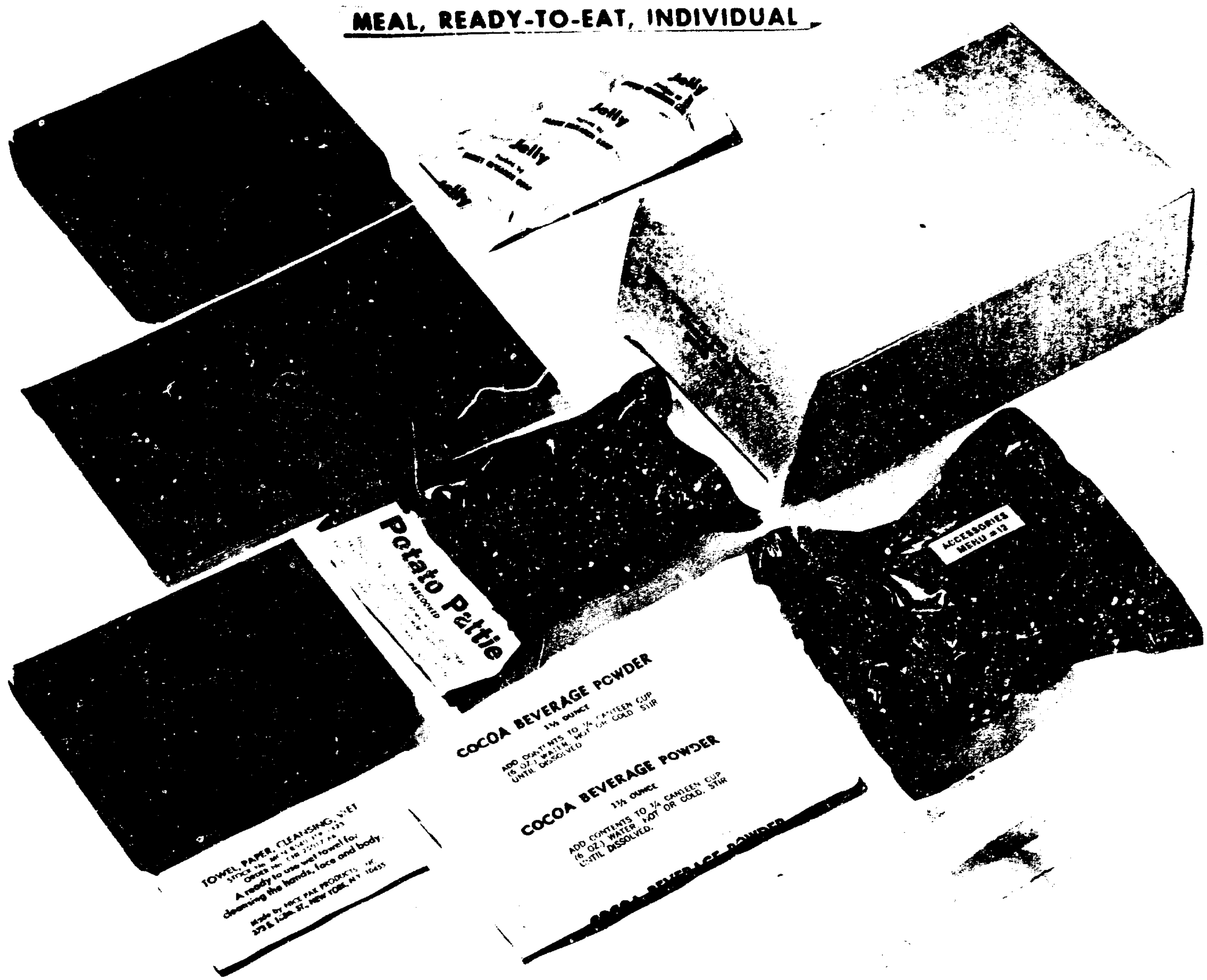


Figure 3. Components of a typical menu (shown with menu carton).

films and laminates were very good barriers to bacteria. Penetration of the test organisms occurred only when a pinhole was present. None of the three-ply laminates had any penetration sites.[14] Pinholes were differentiated from other possible penetration, such as growth or diffusion, by light transmission examinations and dye penetration. There was no indication of bacteria growing or diffusing through the materials themselves. Similar evidence was published after 18 commercially available flexible films were evaluated for packaging radiopasteurized fishery products.[15, 16]

Another significant finding by FMC was related to the effect of retorting on the aluminum foil interlayer of laminates. It was found that retorting produced minute fractures in the aluminum foil: however, they did not extend through the outer plies of plastic. No penetration occurred through these laminates.

It was also found that creasing the three-ply laminates, although considered quite severe, did not influence bacterial penetration.*

An extreme measure of the resistance of materials to microbial attack or penetration was obtained in a soil and climatic test by NLABS. Accordingly, forty thermoprocessed pouches with nutrient broth were prepared and exposed as shown in Table I.

TABLE I

Soil and Climatic Test

| Test Environment | Media for Microorganisms | No. of Pouches | Failures after 8 Months |
|---|---|---|---|
| Burial in soil at tropical room conditions | Broth to recover bacteria | 10 | 0 |
| | Broth to recover mold and yeast | 10 | 0 |
| Hanging in atmosphere at tropical room conditions | Broth to recover bacteria | 10 | 0 |
| | Broth to recover mold and yeast | 10 | 0 |

NOTE: Tropical room conditions -- temperature: 85° to 95°F. relative humidity: 95%.

*Reference is made to the creasing procedure described in the Paper Trade Journal, 118, No. 2, p. 30, 1944.

After eight months of exposure, none of the pouches had been affected in any way by the test conditions. Confirmatory recovery and enrichment of the contents showed that no bacterial recontamination had occurred.

The bacteria penetration studies lead to the conclusion that laminates selected for heat-processed foods are inherently resistant to penetration by microorganisms, and penetration occurs only because of physical damage to the material or package. Recognizing the need for a standard, reproducible laboratory method for evaluating the integrity of flexible packaging systems, NLABS entered into an agreement with Continental Can Company to study this problem.[17, 18] An abuse cycle and bio-test procedure was developed to measure penetrability of a pouch. The severity of the abuse cycle was designed to be equivalent to ten days of Army field use. The Continental work illustrates the superior performance of their R-2 retort pouch structure containing a food contacting film of C-79 polyolefin rather than Rilson (polyamide), Marlex 6050 (polyolefin), and Vitel 409 (polyester).*

Based on the type and amount of evidence documented, it can be asserted that the laminated material NLABS is specifying is pinhole free, and as long as the material remains intact that bacterial penetration will not occur. It is structurally sound and impermeable to bacteria. The material, as specified, is a three-ply lamination containing 0.5-mil polyester/0.35-mil aluminum foil/3-mil polyolefin (heat-sealable).

4. Processing.

Assurance of sterility in thermally processing flexible packages of foods has been discussed, analyzed, and solutions ascertained by several authors in literature.[19, 20, 21] A contract related to this area was also completed by Michigan State University.[22, 23] Important aspects covered include mode and rates of heat penetration into plastic pouches, requirements for controlled arrangement and support of the pouch during processing, insertion, and location of thermocouples in the pouch to assure repeatable and representative temperature measurement, and the mechanics of the heat-processing operation. There is agreement in the scientific community that commercial canning methods for attaining sterility are directly adaptable for use with flexible packages.

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*Rilson: a product of Aquitaine-Organico.
Marlex 6050: a product of Philips Petroleum.
Vitel 409: a product of Goodyear Tire and Rubber.

With commercially available still retorts, processing methods used for glass containers, i.e., water with superimposed pressure, have been used successfully with the assistance of racks to maintain the original shape and integrity of flexible containers. Inoculated pack and heat penetration studies show the graphical method (the method of Bigelow)* to be a valid means of establishing a thermal process for pouches in racks under water.[24] Test results indicate that a process based upon heat penetration data at the cold spot or geometric center of the pouch and an Fo** value that would be assigned to the same amount and character of product in a metal can would be adequate to provide commercial sterility. With continuous sterilizers, such as the Robins Hydrolock, pouch processing has been carried through hyperbaric steam-air mixtures to avoid misshaping thin-wall containers or causing mechanical damage. Although the U. S. Army has not had any experience in processing pouches in continuous sterilizers of this type, others have in this country and abroad.[25, 26, 27]

Realizing some of the advantages of steam-air as a medium for processing pouches, NLABS did investigate its behavior in commercial, vertical, and horizontal retorts and commercial pasteurizers. Michigan State University under contract developed procedures for using steam, steam-air, and water as heating media for flexible containers in both laboratory and commercial processing equipment.[22, 23] Heating rate studies were conducted using pouches and cans. As poinced out in the MSU reports, all three heating media will produce predictable and reproducible results. Steam-air mixtures and water processes may be used effectively for processing flexible packages in systems where there is positive flow of the heating medium. The type of heating media will not measurably affect the quality of the food in the package when equal thermal processes are used. The package geometry is more important. (The flexible package has a small

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* The three methods which are commonly used in analyzing the data are usually referred to as the graphical method, the formula method, and the nomogram method. These methods are described by Bigelow, Bohart, Richardson, and Ball in the publication entitled "Heat Penetration in Processing Canned Foods", National Canners Association Bulletin 16-L, August 1920. The three methods are also summarized in a later publication by the American Can Company, Research Division, Maywood, Illinois, entitled "Calculation of Processes for Canned Foods", January 1950.

**Symbol for sterilizing value. The equivalent value of the process in terms of minutes at 250°F when no time is involved in heating to 250°F or cooling to sublethal temperatures.

thickness through which heat is transferred only a short distance to the geometric center of the food. It therefore heats rapidly with minimum overheat to destroy the quality.)

Since the heat process is based on the heat transfer characteristics of the food product in the retort under actual processing conditions, the heat process will vary with the physical system and the heating medium used in standard practice. This is important in flexible package processing where separation racks must be used. The racks must not only permit but encourage flow of the heating medium in the vertical direction. This requirement is most critical for water but applies also to both 100% steam and steam-air mixtures.

Initial procurements made by NLABS in quantities of 10,000 to 20,000 packages of various fruit, vegetable, and meat items were successfully made in canning plants with conventional retort equipment. Later productions of over 100,000 packages of various meats for military tests further demonstrated that the thermal processing could be made adequate. Evidence of satisfying this basic requirement was substantial when samples from the productions were appropriately incubated and bacteriologically examined as part of the contract inspection requirements.* During one production of three meat items -- weiners, beefsteaks, and beef with barbecue sauce -- which were incubated ten days at 100°F., the products were tested for sterility by Standard Plate Count and Thioglycollate Enrichment Tube test methods. The process given the packages was concluded to be adequate.[28] In another production, approximately 1400 sample packages of seven meat products representing 76 lots of product (92,000 pouches) were likewise tested and found commercially sterile.[29] Samples from the productions were placed in 70°F. and 100°F. storage and periodically evaluated over a two-year period for acceptance. Plate counts, pH, and animal toxin tests were conducted on the samples prior to sensory evaluation. In all the productions and inspections conducted, no underprocessed product was encountered.

A conclusion which can be drawn from the processing work done with regard to safety is that botulism is no more of a problem with flexible containers than with rigid containers. Botulism from canned foods has always been associated with underprocessing. All of the factors that affect the heat process for cans also apply to flexible containers. Primarily, the heat process must be properly designed to inactivate the heat-resistant, pathogenic, and spoilage organisms or spores present which would spoil the food under normal conditions of storage. Invariably, the heat process must be at a sufficiently

*Reference is made to the methods described in "Request for Proposals" No. AMC(X) 19-129-66-267-P.

high temperature and for a specific length of time to be certain of the destruction of any bacterial spores and toxins which might be present. Although productions were made under less than ideal conditions, the U. S. Army was able to process in commercial plants and achieve commercial sterility.

5. Tests and Procedures.

To evaluate the durability of flexible packages for heat-processed foods, the hazards of each step from product to package to consumer were studied then reproduced in a simplified form under controlled conditions. Tests and specifications for packaging materials and containers were drawn and developed from experience and related technical information and promulgated in limited procurement documents (LPD's) for various products. All of the tests as applied throughout development such as seal strength, leakage, volume of residual gases, internal pressure tests, et cetera, are too numerous and varied to be included in this discussion. Some are mentioned in the text of this report, in LPD's, in standards of the American Society for Testing and Materials, the Packaging Institute, Inc., the Technical Association of the Pulp and Paper Industry, and Federal Test Method Standard No. 101. A few others, however, are worthy of mention and description here.

A series of laboratory tests were made with the three-ply thermoprocess pouches to determine the abuse resistance of the pouch with and without folders.[30, 31] The rough handling tests included abusive retorting, vibrating, rotating, tumbling, and guided drop. The results of these abusive tests illustrate how durable this three-ply pouch really is. They give an idea of what types of failure to expect and can also act as a basis for performance tests. The following data were obtained in the tests described. The pouches in tests a through d were filled with 100 ml of water and acid fuschin dye. In test e they were filled with 4-1/2 ounces of chicken-ala-king.

a. Abuse retorting. Fifty pouches were abuse retorted with a water cook at 250°F. with 20 psi overriding pressure. The pressure was modulated $\pm$ 2 psi every two minutes for thirty minutes. The pouches were water-cooled to 160°F. under 20 psi. None of the pouches leaked.

b. Vibrator. The vibrator rotates in a vertical plane one inch across by 1/2 inch. An electric motor maintains this cam-operated motion at 268 cycles per minute. The resulting acceleration is one G. Six pouches were glued to a board and placed on the vibrator for one hour. The pouches showed some strain. but there were no pinholes.

c. Rotator. The rotator was a flat wooden board attached at midpoint to a slow speed electric motor. A silicone rubber adhesive was used to glue pouches to the board. Four pouches were glued with their centers nine inches from the axis of rotation and parallel to the plane of rotation. The board rotated at an average speed of 30 revolutions per minute. The liquid within the pouch flowed back and forth and flexed the package the same way every time. After 39,400 revolutions the pouches were slightly discolored where they strained, but there were no leaks.

d. Revolving hexagonal drum. The revolving hexagonal drum used was a scaled-down, half-size version of the seven-foot-diameter drum described in ASTM D 0782-68.* It is a regular wooden hexagonal drum, 22 inches on a side, which rotates at two revolutions per minute -- 12 drops per minute. The baffles inside the drum flip the pouches over from one side to the other. Drop height is about 20 inches. A summary of data from retorted and unretorted pouches with and without folders is given in Table II. With this abuse method, damage to the pouches was caused by abrasion rather than flexure.

TABLE II.

Revolving Hexagonal Drum Test.

| | No. of Pouches | Type | No. of Drops | Damage Rate | Damage Type |
|---|---|---|---|---|---|
| Unretorted | 6 | No folder | 3,600 | 4/6 | Abrasion leaks in corners |
| | 5 | Fiberboard folder | 3,960 | 0/5 | Folders worn; no leaks, pouches showed slight straining |
| Retorted | 10 | No folder | 3,600 | 10/10 | Abrasion leaks in corners |
| | 5 | Fiberboard folder | 7,920 | 0/5 | After corners of folders wore away, abrasion was noted on pouches |

*American Society for Testing and Materials Standard ASTM D 0782-68 1970 Annual Book of ASTM Standards. Paper, Packaging, Cellulose, Casein, Flexible Barrier Materials, Leather: Part 15, 227. Standard Method of Testing Shipping Containers in Revolving Hexagonal Drum.

e. Guided drop. The guided drop apparatus was a 3" by 20" by 43" fiberboard chute designed and constructed to control the location of impact of a falling pouch. Using this apparatus, the pouches without folders were dropped from a height of 5 feet onto their edges and corners. Face drops were accomplished by free fall without the chute.

Five pouches were dropped a total of 25 times on edges, faces, and corners; 5 pouches were dropped a total of 50 times; and 5 pouches were dropped a total of 75 times.

The pouches suffered considerable fatigue (flexing) from this method of test but no continuous or concentrated stress on any one point. Foil breaks occurred in regions of repeated impact but no complete breakthrough was found. The findings were verified by biotests; all 15 samples passed.

To gain further knowledge of the behavior of flexible packages under stress, a direct comparison of metal cans and flexible packages in a laboratory rough handling test was made. The test showed equal performance of metal cans and flexible packages based on bacterial penetration after biotesting. Superior performance was obtained with the flexible packages when established defect criteria, dents for metal cans, were considered. The procedures, data, and brief discussion of the results are given below.

Commercial metal cans, size 300 by 200, containing 5-1/2 ounces of chicken and noodles were compared with laboratory prepared pouches filled with 4-1/2 ounces of chicken-ala-king. The cans and pouches were packed separately 72 per case in shipping containers of the same domestic class, grade, and style. Weights of the individual cases were approximately 32 pounds and 24 pounds, respectively.

Ten cases of cans and ten cases of pouches in folders (5 cases with pouches on edge and 5 cases with pouches flat) were subjected to one hour of vibration at 268 rpm (one G). Diagrams A and B in Figure 4 describe the packing positions. The method is in accordance with ASTM D 999-68, procedure A.* At the completion of the vibration period, the cases were subjected to 10 drops from a height of 18 inches, in accordance with ASTM D 775-68,** objective B in the prescribed sequence which is as follows:

*1970 Annual Book of ASTM Standards. Paper, Packaging, Cellulose, Casein, Flexible Barrier Materials, Leather. Part 15, 336. Standard Method of Vibration Test Shipping Containers.

**Ibid. 195. Standard Method of Drop Test for Shipping Containers.

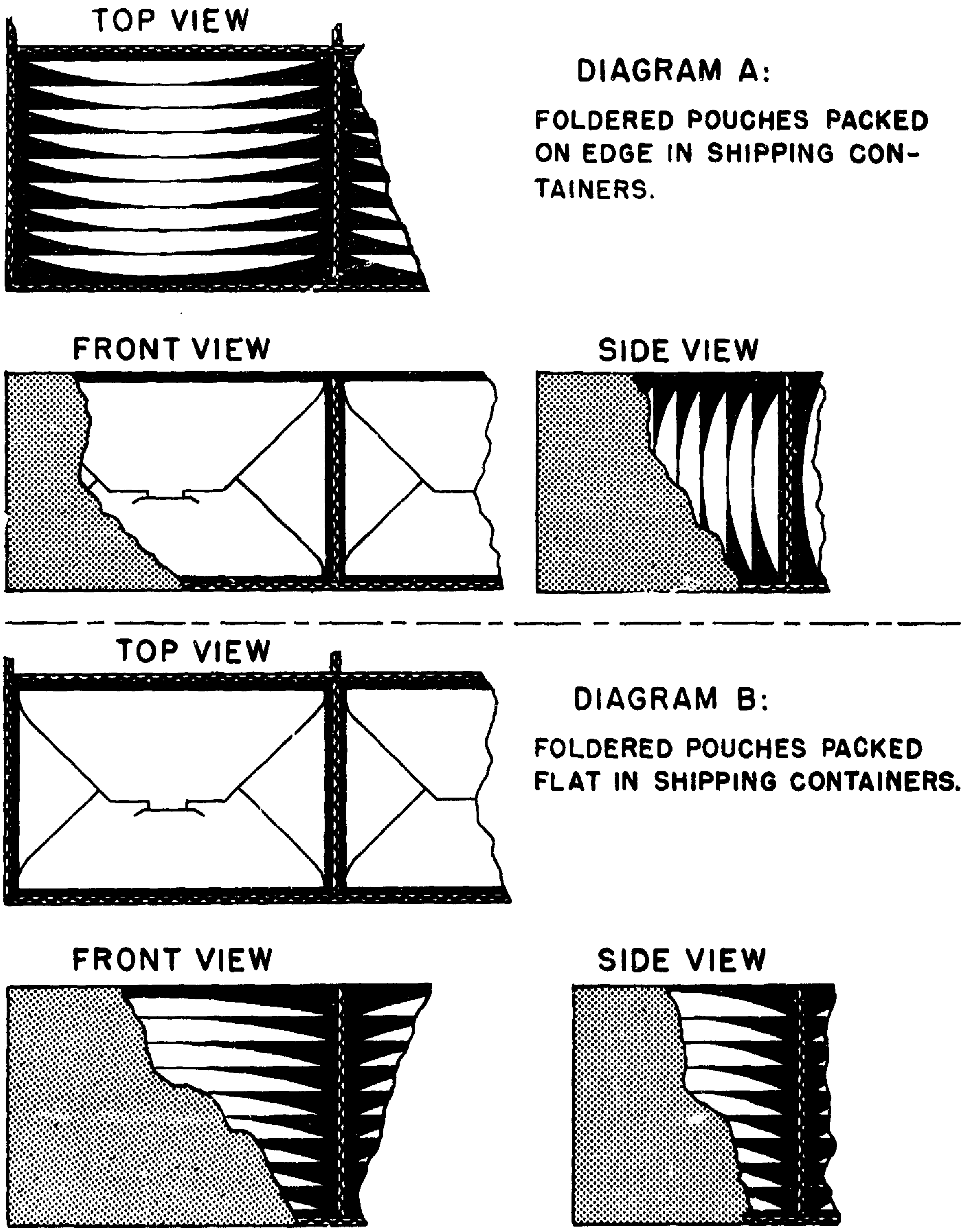


Figure 4. Packing positions of flexible packages.

Drop No. 1 -- A corner drop on the 5-1-2 corner.

2 -- An edge drop on the shortest edge radiating from that corner.

3 -- An edge drop on the next shortest edge radiating from that corner.

4 -- An edge drop on the longest edge radiating from that corner.

5 -- A flat drop on one of the smallest faces.

6 -- A flat drop on the opposite smallest face.

7 -- A flat drop on one of the medium faces.

8 -- A flat drop on the opposite medium face.

9 -- A flat drop on the largest face.

10 -- A flat drop on the opposite largest face.

Figure 5 shows the identification system for the faces, edges, and corners of the cases.

After the rough handling tests the containers were opened, the pouches were removed from their folders; both cans and pouches were examined for damage and leakage, then biotested.

f. Biotest.

(1) Can biotester. The can biotester is a device designed to flex cans while immersed in a water solution containing test microorganisms. The cans are placed in a vacuum jar containing a 24-hour culture of *A. aerogenes*, a gas producing microorganism. The cell concentration is $1 \times 10^6$ cells per ml of water. The vacuum jar is closed, and a vacuum is drawn. Mechanical valves and a timer fluctuate the vacuum between 17 and 27 inches and cause the can ends and sides to flex. This action tends to aspirate bacteria located at a point of microleakage into the can. The vacuum is drawn at a rate of 17 seconds per cycle. The cans were flexed for 90 cycles. They were then removed, examined for damage, and placed in storage at 95°F. for ten days. This storage period was to allow any organisms that penetrated into the can to reproduce in sufficient quantities to cause swelling.

(2) Pouch biotester. The biotester for pouches is essentially a mechanical device designed to create a pressure differential

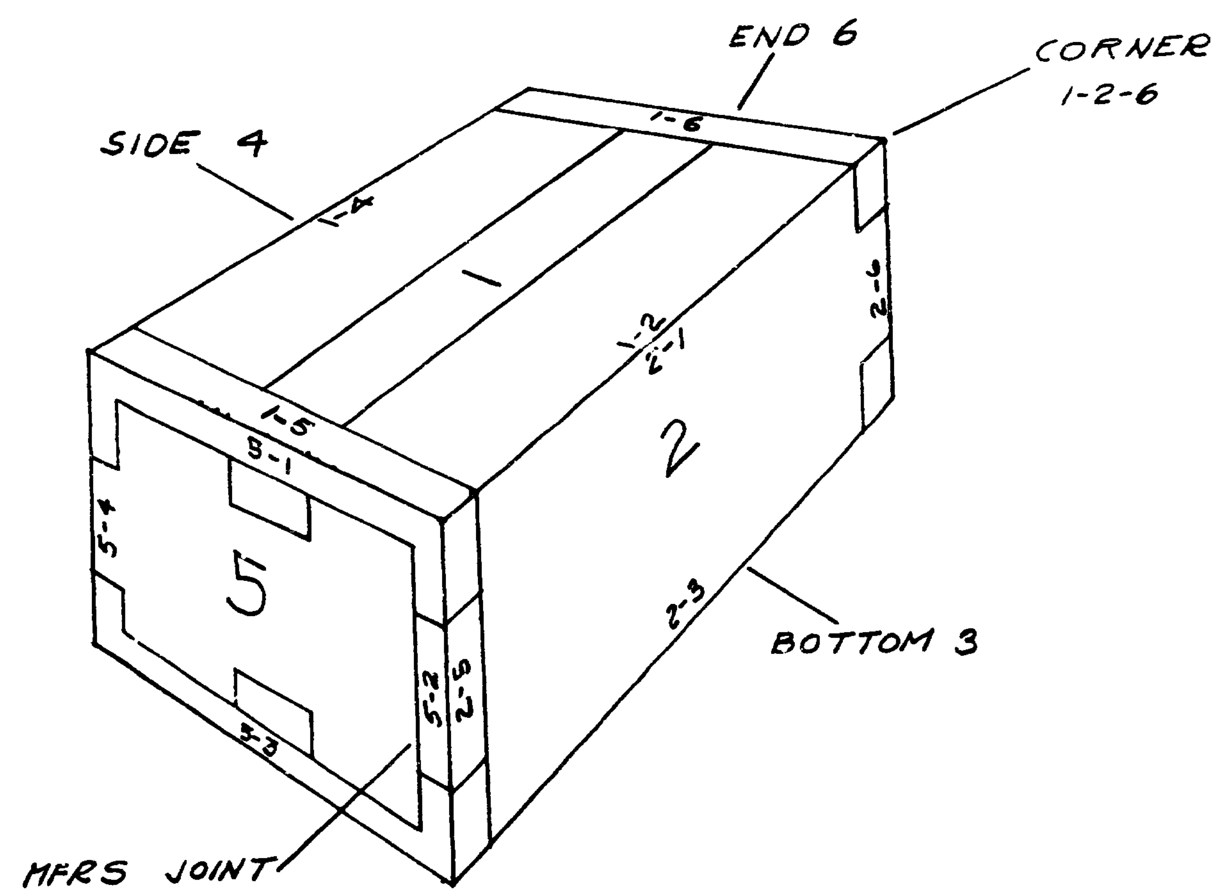


Figure 5. Identification of the faces, edges, and corners of shipping container.

while it is submerged in a water solution containing microorgansms. Two metal channels 1-3/4" wide and spaced 7/8" apart are pressed in an alternating sequence across the 4-1/2" width of the pouch. This kneading action tends to aspirate bacteria, located at a point of microleakage, into the pouch. This kneading action is provided by two pneumatic tubes resting in the metal channels. The pneumatic tubes are pressurized alternately (pressure = 5 psi) at a rate of 45 seconds per cycle.

The pouches removed from the paperboard jackets were placed into the biotester, and the biotester was placed into a tank of water containing a 24-hour culture of A. aerogenes. The cell concentration was 1 x $10^6$ cells per ml of tank water. The pouches were flexed for 90 cycles. Upon completion of the 90 cycles the pouches were removed examined for leakage, and placed in storage conditions of 95°F. for ten days.

(3) Controls. At the beginning and end of each day's biotesting, a can and pouch were injected with 1.5 cc of solution from the inoculated baths used for their respective tests.

(4) Results. Those cans and pouches that were defective due to rough handling allowed microbial penetration because of the biotest treatment and became obviously swollen. The can ends distended, whereas the pouch took on a cylindrically shaped configuration. Both types of deformation were readily noticeable to the naked eye. The swelling of can or pouch during storage was considered an indication of failure. There was one can that failed during rough handling and was detected during an examination for leakage after rough handling, and it was not biotested. All other failures were detected during storage. The results were as follows:

TABLE III.

Biotest.

| Item | Quantity | Number of Failures | | | Percent Failures |
|---|---|---|---|---|---|
| | | Before Biotest | After Biotest | Total Failures | |
| Cans | 720 | 1 | 14 | 15 | 2.08 |
| Pouches | | | | | |
| Flat | 360 | 0 | 8 | 8 | |
| On Edge | 360 | 0 | 6 | 6 | |
| Total | 720 | 0 | 14 | 14 | 1.94 |

A large number of cans suffered damage and denting during the drop tests. These cans were classified on the basis of definitions contained in the Visual Inspection Gauge Set No. 33A-2D, Standard Classification for Can Defects.* The classifications are (1) Major Defect is one that is likely to reduce materially the usability of the unit of product for its intended purpose; (2) a Minor Defect is one that is not likely to reduce materially the usability of the unit of product for its intended purposes, or is a departure from established standards having little bearing on the effective use or operation of the unit. In addition, the degree of severity of a minor dent was designated.

After examination of those cans that did not swell, the damaged cans were put into the classifications shown in Table IV.

TABLE IV.

Can Classifications

| Defects | Quantity |
|---|---|
| Major | 8 |
| Minor -- upper limit | 18 |
| lower limit | 22 |

(5) Discussion. During the drop test procedure all of the fiberboard containers of cans suffered severe damage on the second or third drop. This damage consisted of complete top and bottom scoreline tearing to such a degree that if the end of the container was not reinforced the contents would have spilled out on one or more drops. In every one of the ten containers of cans, the ends were reinforced by means of a single strip of 3"-wide cloth tape.** In two out of the ten containers, the drop following the application of tape, the tape tore completely through and another piece of tape was applied over the first piece. If this test was one in which the fiberboard containers were being tested, all containers would have failed after their third drop, and the test would have stopped. There were no signs of any type of damage to the

*Visual Inspection Gauge Set No. 33A-2D. Standard Classification for Defects. Headquarters, Military Subsistence Supply Agency, Quality Control and Inspection Division, 1 December 1960.

**Federal Specification, PPP-T-60, Tape, Pressure-sensitive Adhesive Waterproof, for Packaging. 8 Oct 65.

containers of flexible pouches other than a crushing of the 5-1-2 corner.

Those flexible packages that swelled in storage were obvious after 24 hours. The cans were not as obvious after 24 hours, and in some instances took as long as 72 hours to deform.

The can damage due to rough handling was extensive to cans in the vicinity of the 5-1-2 corner and one or two cans next to that corner. This was true in all three layers. Those cans away from that corner experienced little or no denting.

The obvious damage to the flexible packages due to rough handling was minimal. The paperboard folder appeared to absorb most of the damage of the drop tests. Those pouches in the 5-1-2 corner showed slight signs of blunted corners or edges, but all others showed no signs of any damage during a visual inspection.

In an attempt to develop tests and methods to detect leaks in pouches, two outside contracts were awarded. One went to the Applied Science Division of Litton Industries, Inc., and the other to the Applied Technology Division of AVCO Corporation.[32, 33] Abstracts of completed work are given below.

g. Litton Industries, Inc. Contract (ASD). The purpose of the study was to develop an alarm system for detection of actual or potential microbial contamination. Efforts were directed toward development of a self-actuating alarm system incorporated as an integral part of the package, and development of a simple carry-along device which could be attached to or carried separately from the package and applied just prior to consumption, to provide an immediate response.

Chemical and biochemical reagents, as well as a limited number of microorganisms, were studied as components of the alarm detection systems investigated. Approaches studied were categorically based on

(1) Package inflation or blistering.

(2) Color-forming reactions.

(3) An enzyme ticket system separate from the container or food.

A lipid-soluble dye system and an ascorbic acid reagent system showed some promise but could not successfully be implemented. Considerable effort was directed to a dye approach based upon the reaction of ninhydrin with foods. The inherent instability of ninhydrin, however, could not be stabilized in a suitable surface matrix and was

abandoned. The most satisfactory reagent system for ascorbic acid in terms of color development was equimolar portions of p-nitroso-N,N' dimethylaniline and p-dimethylaminobenzaldehyde. Unfortunately, this reagent melts below 100°C and gives a false positive color with boiling water. These systems also needed better methods to promote flow-through package holes which are not practical. The transport of food liquids through small holes is unreliable due to the great variation found in the viscosity of food fluids, their tendency to harden in air, and other factors.

In this study, no feasible leak detection system was developed.

h. AVCO Contract. The purpose of this study was to develop a nondestructive test method (or methods) for positive detection of body leaks or perforations in pouches. Of the many techniques surveyed by NLABS and the contractor, two techniques considered feasible were studied in depth during the second phase of the contract: electrical conductivity and helium detection.

The capabilities of an electrical conductivity technique and a helium detection technique were evaluated. In the former, using a salt water solution as a simulated food product, test procedures and apparatus were developed. It was found that this solution could be detected escaping from holes larger than 30 microns if reasonable forces were applied. Tests with actual product, however, were not reliable to detect holes less than 100 microns in diameter. (Holes approximately 100 microns in diameter can be detected with the naked eye and product will exude through such holes on application of pressure.[34]) Tests of the helium detection technique were more informative. The following recommendations were made:

(1) The helium detection technique is a valuable research tool and should be used where required in laboratory programs.

(2) Defects within the sizes specified can be detected, and if the government desires to implement the technique in a production facility, a design effort should be initiated. (For dry foods, defects as small as 30 microns are detectable; for wet foods, defects at least as small as 70 microns, and possibly as small as 55 microns can be detected. Dry foods are those with no free fluid and of a texture characterized as solid, e.g., beefsteak, chicken loaf, etc. Wet foods are those of low viscosity, fluid components such as chicken ala king or beef slices with barbecue sauce.)

(3) A more economical solution to the nondestructive test problem might be found in a study of a large sample of food packages. Statistical results could then be used to evaluate the production

procedures. Thus, full implementation of the helium detection technique could be avoided.

In summation, controlled abuse testing as described above illustrated the overall strength of the flexible package. Laboratory tests, coupled with practical experience in field trials, permit logical and accurate judgments to be made in rations or similar applications. Appraisal of both types of data indicates the flexible package is adequate for heat-processed foods. Field trials will be covered in the discussion areas to follow. Based upon experience to date, there is no valid need for an alarm system or leak detection system for flexible packages.

6. <u>Shipment and Storage</u>.

The flexible package was tried as a proposed replacement for rigid metal cans in special-purpose rations. One of the trials was in the Meal, Ready-to-Eat, Individual. An integrated Engineering Test and Service Test (ET/ST) of the meal was conducted by the U. S. Army Test and Evaluation Command. Prior to troop issue in the ET/ST, inspections were made to determine the capability of the meals packed for overseas shipment to withstand handling during transportation from point of ration assembly to test site. Approximately 4,000 cases (12 meals per case) of test items had been shipped from Kansas City, Missouri (the point of assembly) to test sites located in Virginia, Georgia, North Carolina, Louisiana, and as far as Panama. Methods of transportation used for these shipments were commercial air freight, rail freight, motor freight, and ship (Panama only). In the shipment to Panama of 1,600 cases, one-half of the shipment was made as individual cases, while the remainder was palletized into 13 unit loads, in accordance with Military Specification MIL-L-35078.* At each destination, a 100-percent inspection and damage analysis was made of all shipping cases and flexible packages. As noted in the final report, the performance of the cases and packages from the shipping and handling standpoint was considered "excellent" for all means of transportation.

Transport of the meals by aerial delivery was also considered. Airdrop testing was conducted utilizing standard, low velocity, and freedrop techniques. U. S. Air Force C-130 and U. S. Army CV-7 aircraft were employed. (The test criteria for aerial delivery without parachute was to assure 75 percent recovery.) Three methods of freedrop without parachute but with energy absorbing honeycomb pads were found satisfactory. One method -- cases airdropped singly without

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*Military Specification, MIL-L-35078, Load, Unit, Preparation of Nonperishable Subsistence in. 20 Jun 66.

honeycomb pads -- was considered a marginal method for delivery without parachute. The latter method had a recovery rate of 76.5 percent. The best freedrop method was to lash four cases together in a cargo sling, A-7A,* with one layer of pads placed around and between the cases; the recovery rate was 94.1 percent. Standard delivery techniques with parachute were satisfactory. Based on the above, the Meal, Ready-to-Eat, meets the requirements for aerial delivery, but to be prudent, the method of freedrop without honeycomb should not be used.

The performance reported for the packaging and components of the meals in the ET/ST with regard to air transit conditions was "excellent". The packaging and components satisfactorily withstood air pressure equivalent to 50,000 feet altitude, 25 percent more than is stipulated in the Army Regulation AR 705-15.**

Storage for three months in a hot-wet environment in Panama as part of the ET/ST showed the performance of the experimental meal in its shipping case was "extremely good". Storage conditions included outside storage of individual cases stacked on pallets and covered with a tarpaulin, outside storage of individual cases without any covering, and inside storage of individual cases. At the end of the storage period, a visual inspection of each case was made, and all cases with any evidence of damage were removed for a detailed inspection. No major problems were observed with regard to insect and rodent resistance of the cases and components; the basic requirements were met.

The flexible package also proved to possess excellent barrier properties when evaluated on the basis of taste-tests before and after periods of controlled storage. NLABS conducted an in-house study to determine the palatability of the Meal, Ready-to-Eat, initially and throughout storage for one year at 100°F and for two years at 70°F. Typical foods tested are shown in Figure 6. The meals were evaluated for preference by the *hedonic scale* test method.[35] A nine-point hedonic scale ranging from *like extremely* to *dislike extremely* was used.

Table V gives the mean hedonic rating for the major food components (wet-packs) in the meal menus. As noted, the ratings for the food items remained sufficiently high and relatively constant

*Described in TM 10-500, Airdrop of Supplies and Equipment, General, 7 May 65.

**AR 705-15 superseded by AR 70-38 Research Development Test & Evaluation of Material for Extreme Climatic Conditions, 5 May 69.

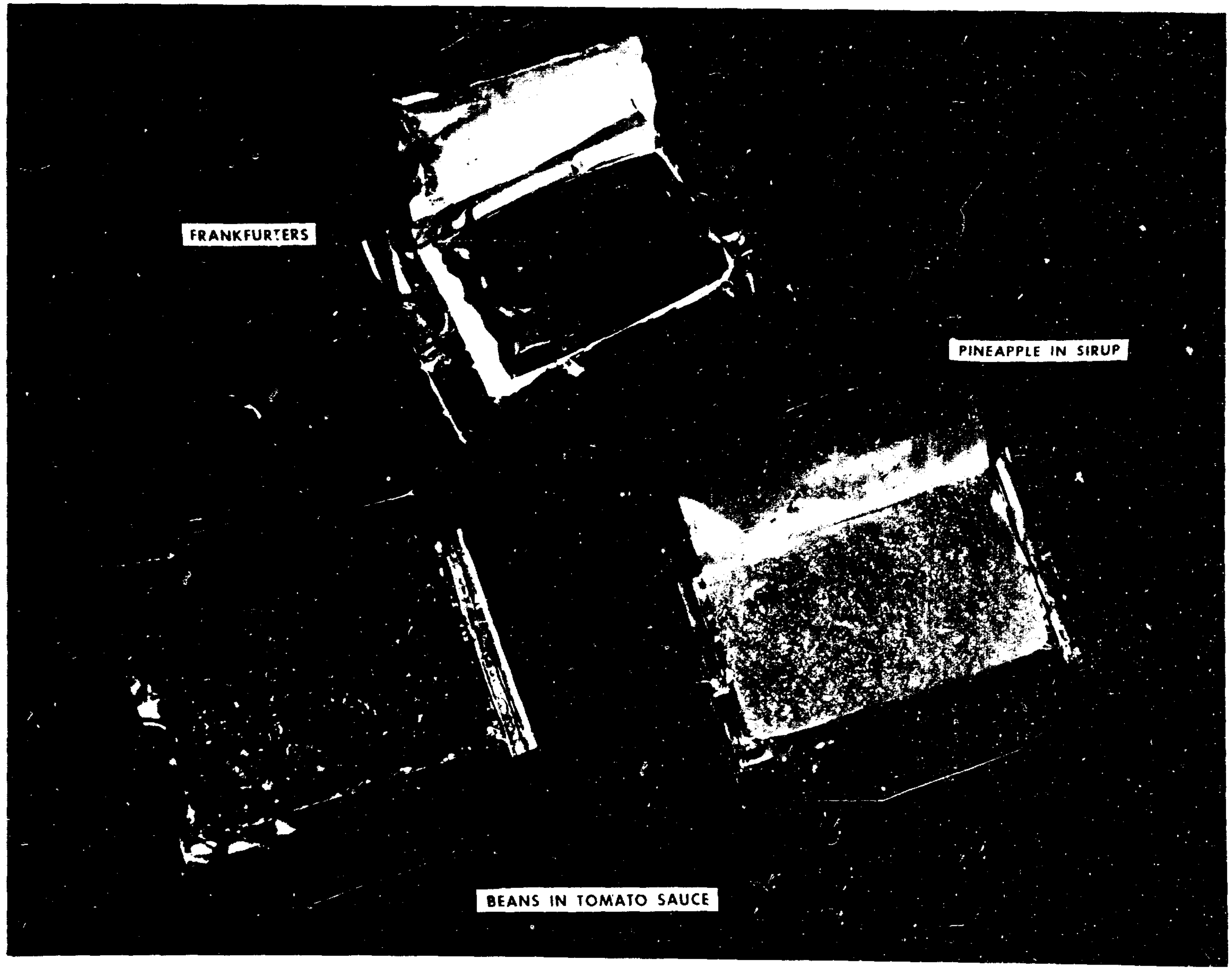


Figure 6. Typical foods in flexible packages.

Table V.

MEAN HEDONIC RATINGS

Heat-Processed Food in Flexible Packages

(Components of the Meal, Ready-to-Eat, Individual)

Before and After Storage

| Food Item | Initial | | 70°F.* (in months) | | | | 100°F.* (in months) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Hot | Cold* | 6 | 12 | 18 | 24 | 3 | 6 | 9 | 12 |
| Pork Sausage Links | 7.7 | 6.9** | 7.3 | 6.8 | 7.2 | 6.7 | 7.4 | 7.4 | 6.9 | 6.0 |
| Ham & Chicken Loaf | 7.5 | 7.4 | 7.3 | 7.2 | 7.0 | 7.5 | 7.1 | 7.4 | 7.0 | 7.1 |
| Beef Slices w/BBQ Sauce | 7.0 | 7.2 | 6.8 | 7.4 | 6.9 | 6.8 | 7.4 | 6.8 | 6.9 | 6.7 |
| Chicken ala King | 7.6 | 7.4 | 7.2 | 7.2 | 7.1 | 7.0 | 6.5** | 6.8 | 7.3 | 7.1 |
| Ground Beef w/Pickle Sauce | 7.6 | 6.4** | 6.9 | 6.8 | 6.5 | 6.4 | 6.7 | 6.9 | 6.6 | 6.2 |
| Beef Stew | 7.3 | 7.2 | 7.5 | 7.2 | 7.2 | 6.6 | 7.1 | 7.4 | 7.1 | 7.0 |
| Frankfurters | 7.1 | 7.2 | 7.1 | 6.9 | 6.9 | 7.1 | 6.9 | 7.1 | 6.5 | 5.9** |
| Beef Steak | 7.0 | 7.1 | 6.6 | 7.0 | 6.9 | 6.4 | 6.6 | 6.5 | 6.0** | 6.0** |
| Chicken Loaf | 7.7 | 7.4 | 6.8 | 7.5 | 7.0 | 7.3 | 7.3 | 6.7** | 7.0 | 7.0 |
| Beef Loaf | 6.7 | 6.4 | 6.6 | 6.5 | 6.9 | 6.0 | 6.9 | 6.4 | 6.5 | 6.6 |
| Beans & Tomato Sauce | 7.3 | 6.8 | 7.3 | 6.9 | 7.4 | 7.1 | 7.3 | 7.7** | 7.3 | 7.4 |

*Item served at room temperature.

**Indicates significant change in rating at the 0.05 level of probability.

throughout the study. In only a few sporadic instances was there a significant change in the rating for the eleven items; however, there was not one item during the entire 24-month period that rated below 5.0, the mean rating generally representing either poor quality food or foods that are strange to the taster. (5.0 on the hedonic scale is described as neither like nor dislike.) When served hot, only two items were rated significantly higher than when served cold they were pork sausage links and ground beef with barbeque sauce. Neither one was disliked. Served cold their ratings were 6.9 and 6.4, respectively.

Throughout the storage study examinations for package integrity were conducted. At no time during storage did the packaging material reveal any signs of corrosion, loss of color, or imparting flavor or odor foreign to the product. Only slight decreases in seal strength, none below the minimum acceptable level, were evident at the end of one year at 100°F. and two years at 70°F. Evidence of spotty delamination was found in a few packages after nine months of storage at 100°F.

To make a concise statement related to shipping, handling, and storage, the flexible package is considered satisfactory for military rations.

7. Consumer Handling.

Engineering-service test reports show that the flexible package is preferred to the metal can with regard to general utility features including ease of carrying, ease of opening, and disposal after use, preference for carrying with regard to size, weight, and shape and general suitability for use under diversified field conditions. Materials and general configuration have been designed to conform with human use factors. In addition, the flexible package has exhibited adequate mechanical strength and durability in user endurance tests.

To determine the performance of flexible packages under conditions which may prevail during their eventual use, packages were subjected to field-durability tests. Several such tests (Engineer Design) were conducted by the U. S. Army Test and Evaluation Command.[36, 37, 38, 39, 40] The first of these was run at Fort Lee, Virginia, and was conducted in two phases. During Phase I a number of troops carried these packages in their pockets during the course of a planned maneuver. The packages were carried in groups of 3, 6, and 9, simulating the carrying of 1, 2, or 3 meals (see Figure 7). Phase II consisted of the troops carrying the pouches in the same manner over an obstacle course which was designed to show accelerated


Figure 7. Soldier carrying nine flexible packages.

wear on combat clothing. Figures 8 and 9 show the types of treatment which the packages received. The results of these tests indicated that the individual packages were satisfactory for field use.

Troop tests of the Meal, Ready-to-Eat, Individual, containing flexible package components were later run. An engineering test of the experimental meal was conducted to determine its suitability with respect to compatibility of the flexible packaging with the pockets of the soldier's field clothing, weight and cube characteristics, and extent of use of the flexible packaging in the meals.[41] Refinements in the design of the meal were made and subsequently engineer and service tested.[11] The ET/ST of the meal showed the durability of the flexible package and the overall performance to be satisfactory. Inspection of the meals for consumption during the field phases, however, showed seal defects and pouch punctures which occurred during manufacturing the food components. As indicated in the first paragraph of Section 6 -- Shipment and Storage -- the shipping cases and individual packages of the meals were all inspected for damage at each test site. Components that were considered potential or actual failures were removed from the meal, and only good packages were troop tested. NLABS scientists conducted the inspections with assistance of test team personnel of the U. S. Army General Equipment Test Activity and the U. S. Army Infantry Board. Further observations made during the field use phases showed no evidence of safety hazards to the user from a handling standpoint.

The inspections of the meals prior to use involved over 50,000 individual packages of meat, fruit, and spread items. Of these, 0.3 percent were faulty due to lack of adequate quality control and operational equipment at the plant of manufacture. Pouches were examined bacteriologically, and spoilage found was due to leakage. A large number of samples examined showed mixed cultures. This suggested that these organisms were introduced via an opening in the pouch which resulted in the presence of these organisms after heat-processing. The major types of failure were closure seal defects and punctures in the face of the pouch. Approximately two-thirds were seal failures and one-third punctures. There was no evidence to associate package failure with shipping and handling conditions.

The summary of findings, as pointed out in the ET/ST report, is that the overall packaging characteristics of the meal are satisfactory except for the 0.3% faulty packages. Although the percent of damage and failure was relatively low, it was deemed a potential safety hazard to the user and declared a packaging deficiency.

Figure 8. Test participant scaling obstacle during accelerated use.

Figure 9. Test participants traversing gravel crawl under wire emplacements during accelerated use.

Recommendations were made that the Meal, Ready-to-Eat, Individual, be considered not suitable for use by the Army until the packaging deficiency is corrected and the modifications are check-tested. Presently, NLABS is in the midst of a program to remove the packaging deficiency, i,e., to reduce the production defects to an acceptable level.

8. Production Capability.

Attempts to produce flexible packages in large quantities for ration purposes revealed the needs for better production facilities and control. Packaging failures that are recognized and acknowledged as on-line defects were not eliminated at the production plant. A program, therefore, was developed to establish the feasibility of obtaining and assuring the reliability of flexible packages for heat-processed foods through the use of an optimally automated production system.

To achieve this objective, NLABS awarded a contract to a team of firms headed by Swift and Co. and including the Pillsbury Company, Continental Can Co., Bartelt Engineering Division of Riegel Paper, and the FMC Corporation. The scope of the work was to accomplish the following:

a. Determine pouch forming, filling, and sealing equipment requirements, including modification of existing equipment to preclude seal area contamination.

b. Set up a prototype line and run a sufficient number (up to 50,000) of representative foods in the flexible package.

c. Establish the reliability for each item.

A reliability goal of no more than 0.01% defective pouches (one defective, filled, sealed, heat-processed package per 10,000) was established. The first phase of the contract proved, within the constraints of bench models and special testing equipment testing, that it is feasible to reliably prepare flexible packages on a production scale.[42] Seventeen items were extensively tested representing a variety of viscosities, mixtures of particles and fluids, and solids. A prototype line was also designed with modifications in existing equipment. Figure 10 shows schematically the production-line concept. Significant features in the design are

a. A carrier system that

(1) Provides a means for closely controlling and positioning the pouch through vacuumizing and final sealing,

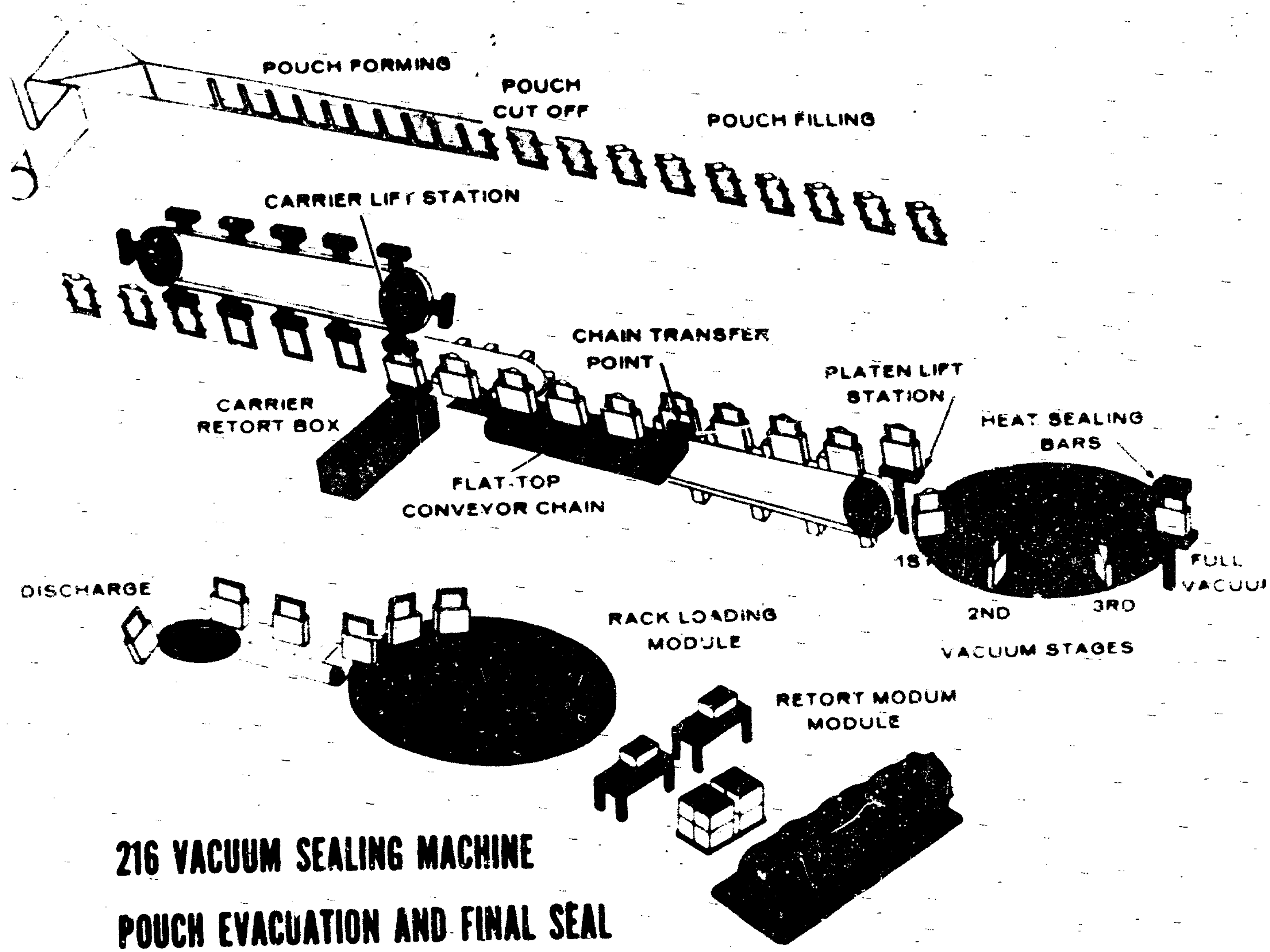


Figure 10. Flexible packaging production-line concept.

(2) Eliminates handling or manipulation of the pouch throughout the production operations, and

(3) Becomes a component of the retort rack providing a uniform thickness and assuring adequate water circulation.

b Modification of a standard can vacuumizing and closing machine to accept the carrier, apply three stages of vacuum, and heat-seal the pouch.

At this writing, the contractor is beginning the final phase of the contract to set up a prototype line and establish the reliability for various food items. This phase is scheduled to be completed in 18 months.

Supplementary measures to prevent and weed out defects in production were developed. Seal failures noted were caused primarily by food, wrinkles, oil, grease, and moisture entrapped in the seal area. Sealing through oil, grease, and moisture has been solved in-house by use of a curved-jaw sealing bar and a silicone rubber anvil system.[43] The problem of sealing through food particles and for eliminating contamination in the seal area altogether are still under study. A system to detect defects in the seals, however, was developed.[44] Figure 11 shows schematically the apparatus used during test runs. It consists of a scanning device which measures changes in infrared radiation along the seal as affected by changes in the seal structure. A single pineapple fiber, a single sugar crystal, and a void in the seal were easily detected. A prototype machine was recently built and passed acceptance tests under contract by Barnes Engineering Co. (see Figure 12). The prototype has an automatic rejection system for on-line examination of closure seals.

Relative to the punctures that occurred in production, experience has shown that such defects can be visually detected. The fact that they were discovered in a visual inspection indicates they can be easily found. Evidence also exists from a 100% visual inspection of approximately 45,000 packages of meats, in which all defective packages were removed, and the remainder were stored in a warehouse at ambient temperature. Six months later, 1,000 packages were randomly selected and reexamined, showing no defects. These samples were then subjected to an internal pressure test of 5 psig while held under water to detect any escaping gas; no defects were found. Subsequently, all samples were subjected to a dye penetration test. In no case did the dye penetrate completely through the three plies of the pouch material. In five cases dye had penetrated a fracture in the polyester and in the foil, but did not penetrate the polyolefin layer.

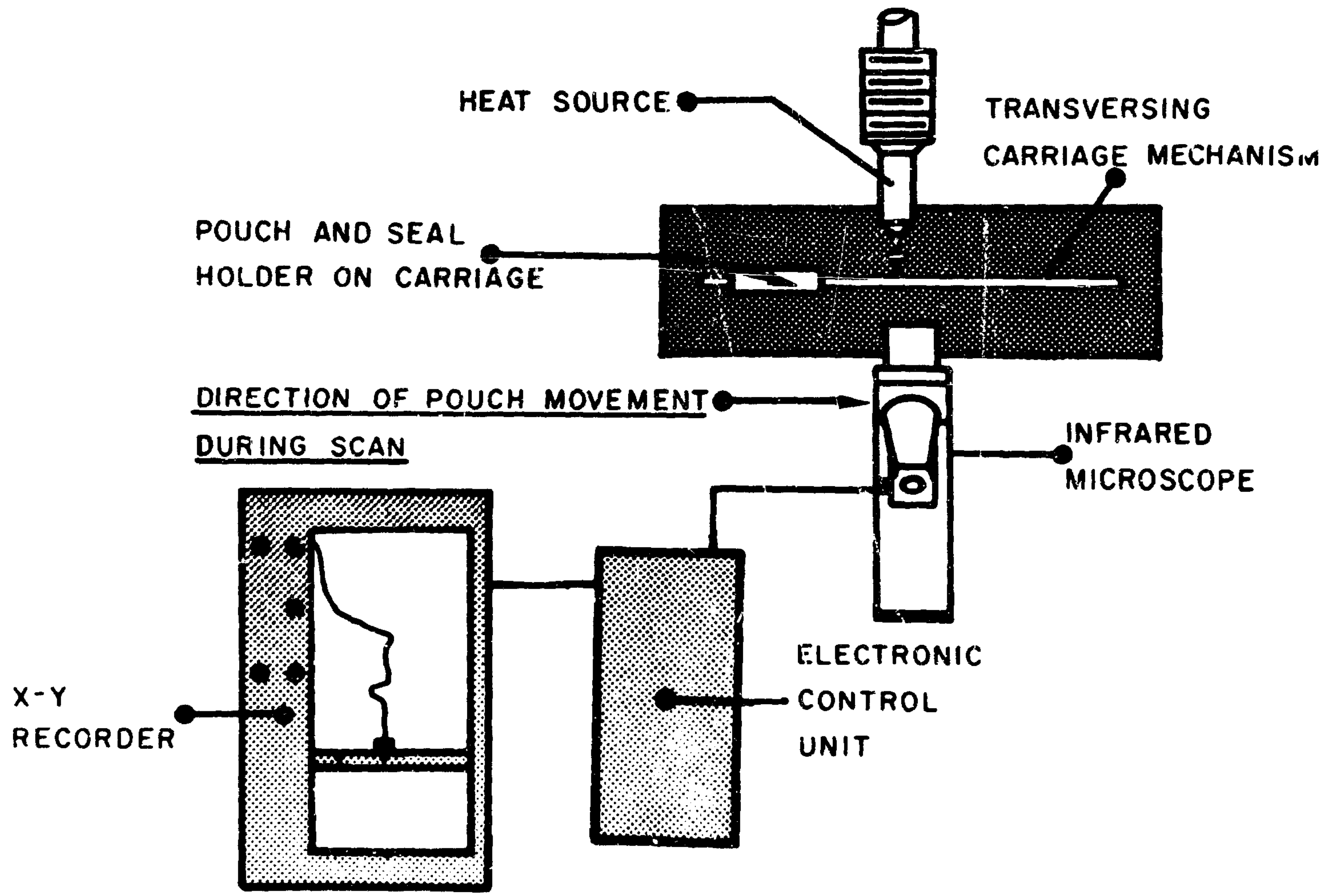


Figure 11. Schematic drawing of infrared seal scanning apparatus. (Top view.)

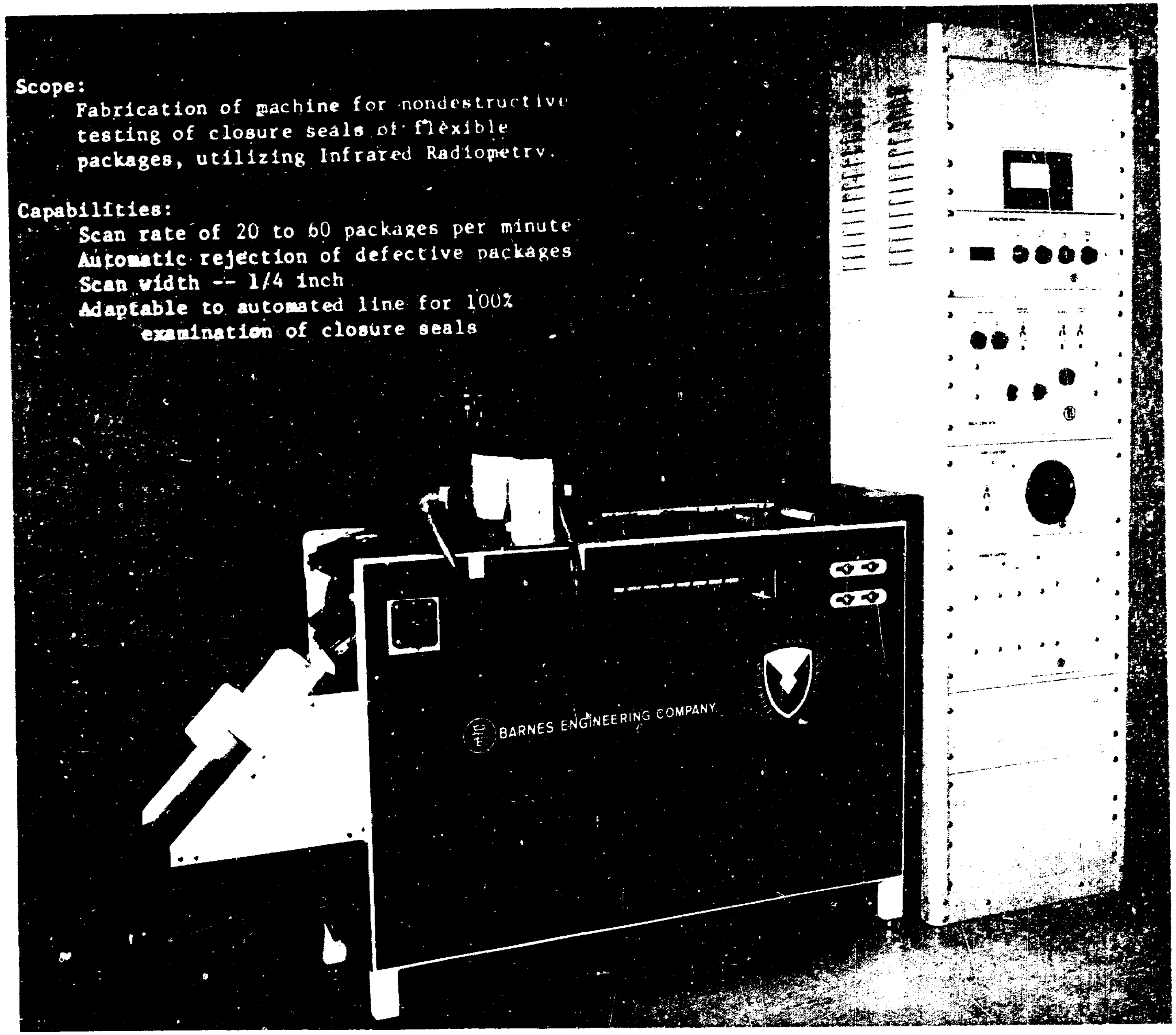


Figure 12. Infrared radiometry seal defect scanner.

The significance of this, from a safety standpoint, should be viewed in the proper perspective. Variables one must first consider relative to bacterial spoilage are as follows.

a. If spoilage organisms are present and enter through such defects, they may grow and spoil the food, provided the environment is favorable.

b. The media from which the spoilage organisms are derived can vary considerably; therefore, the type of infection which may be encountered is unpredictable.

Recognition of spoilage, like in cans, will depend upon the types of organisms present and their activity. Since spoilage may assume different forms, as indicated by leakage, putrefaction, swellers, etc., in cans, it is imperative that postprocess contamination be prevented to the maximum extent. To assure this, the container must be sound and sufficiently durable to withstand the hazards of its use. Extensive testing has demonstrated that the flexible package is sufficiently durable for field use by the Military. It must be also realized that there is no absolute guarantee which can be issued in this respect for cans or other containers. One must weigh the assets of each container.

In many instances relative to recognition of spoilage, the assets possessed by the pouch for heat-processed foods outweigh those possessed by cans. The flexibility of the pouch allows for rapid expansion and aids in the detection of chemical or microbial changes. In contrast to cans which are rigid, the pouch swells readily when exposed to slight pressure differentials. Therefore, when gas-producing organisms are involved in spoilage within a pouch, it can be detected faster and easier. The exposed seals of the pouch reveal defects such as wrinkles, occluded matter, and voids. Seal defects in cans are generally more difficult to find because they are concealed in the double seam. The latter often requires a qualified technician to tear down the seams in search of conditions of poor quality or damage. And last, can spoilage does occur with cans of good commercial quality.[45] Temporary disturbance of the double-seam compound can take place at a crucial time when microorganisms are present. With the pouch the seals are fused and cannot be temporarily disturbed.

In conclusion, there is a production problem of producing and accepting defective pouches at a rate greater than 0.1% (one unit per 1,000) that remains to be solved. The practical approach to safeguards in this respect is through equipment modification, better

quality control, and adequate quality assurance provision in flexible packaging specifications intended specifically for heat-processed foods. Programmed efforts in the solution are progressing satisfactorily.

## SUMMARY

In summarizing the significant findings of research and development work completed to date and assessed in each section in this document, the following statements are made:

1. Materials. Flexible materials are presently available that possess the essential properties to package shelf-stable, heat-processed foods.

2. Package Design. A flexible packaging system for heat-processed foods -- a pouch and folder joined together -- that has logistical and user advantages is suitable for military needs.

3. Bacterial Penetration. Laminated aluminum foil materials specified for heat-processed foods are structurally sound and impermeable to bacteria.

4. Processing. Canning methods to achieve commercial sterility can be safely adapted for use with flexible packages.

5. Tests and Procedures. Laboratory tests coupled with field trials show the overall strength of the flexible package is satisfactory. Based upon experience to date, there is no need for a leak detection system for this package. Leaks can be eliminated by exercising reasonable care and common sense to avoid abuse during production. Regarding autodetection, there is no more need for such a device with flexible packages than with cans.

6. Shipment and Storage. Shipping and handling characteristics are considered excellent for all means of transportation. Suitable methods are also available for aerial delivery. Palatability of meat items stored for periods of 12 months at 100°F. and two years at 70°F. remains relatively uniform and acceptable throughout storage.

7. Consumer Handling. Use under diversified field conditions shows that the flexible package is preferred to the metal can with regard to general utility features including ease of carrying; ease of opening and disposal after use; preference for carrying with regard to size, weight, and shape; and general suitability. In addition, the flexible package has adequate mechanical strength and durability.

8. Production Capability. There are needs for better production facilities and for control to produce heat-processed foods in flexible packages. Under an existing contract, an industry team headed by Swift and Co. has proved, within the constraints of bench models and special equipment testing, it is feasible to reliably prepare flexible packages on a production scale. An optimally automated system has been designed, and a prototype line is being built to establish the packaging reliability for various food items. A system to detect defects in the seals was also developed, which should help weed out defects in production. A prototype machine was built with an automatic rejection system for on-line examination of closure seals.

In the final analysis, review and evaluation of available data show that adequate information exists, or is actively being pursued, to provide assurance toward the acceptability of flexible packages for heat-processed foods.

## LITERATURE CITED


1. Keller, R. G. Flexible packages for processed foods. QMFCIAF Report No. 31-59, Technical Report No. 208, December 1959 (AD 233035).*

2. Luh, B. S. and Guillermo de la Hoz. Packaging of foods in laminate and aluminum-film combination pouches. Food Technology, 228 (1474), September 1964.

3. Luh, B. S. and J. M. Tsiang. Packaging of tomato ketchup in plastic laminate and aluminum foil pouches. Food Technology, 96 (396), March 1965.

4. Nieboer, S. F. T. Flexible vacuum packs for processed vegetables. Food Manufacture, 70, February 1970.

5. Heidelbaugh, N. D. and M. Karel. Changes in pouches heat-processed foods. Modern Packaging, 80, November 1970.

6. Killoran, J. J., J. D. Loconti, and R. C. Bouchmer. Delamination of multilayered flexible materials for identification and thickness measurement of component layers. Unpublished NLABS data, March 1970.

7. Karel, M. and G. N. Wogan. Migration of substances from flexible containers for heat-processed foods. Report of QM Research Contract DA-19-129-QM-2080, Massachusetts Institute of Technology, June 1963.*

8. Ferm, R. L. Migration of flexible packaging components into foods. U. S. Army Natick Laboratories, Technical Report 66-56-CD, June 1966 (AD 640522).*

9. Rubinate, F. J. Flexible packages for heat processed foods. Proceedings of the Thirteenth Research Conference, American Meat Institute Foundation, University of Chicago, 107, March 1961.

10. Leinen, N. Aluminum cans can be practical now. Food Processing, 25, April 1959.

11. Paschall, H. H. Integrated engineering and service test of meal, ready-to-eat, individual. Report of USATECOM Project No. 8-3-6400-06/07/08, June 1967 (AD 817616L).*

12. Proctor, B. E. and J. T. R. Nikerson. Investigation of bacterial resistance of packages. Report of QM Research Contract DA-19-129-QM-758, Massachusetts Institute of Technology, March 1958.*

13. Lampi, R. A. Resistance of flexible packaging materials to penetration by microbial agents. U. S. Army Natick Laboratories, Technical Report 67-62-GP, April 1967 (AD 651493).*

14. Griffin, R. G., M. H. Nograti, R. A. Lampi, and J. W. Szczeblowski. Bacterial resistance of films. Modern Packaging, 164, October 1967.

15. Ronsivalli, L. J. Problems in packaging radiopasteurized fish. Activities Report, Research and Development Associated, 19, (1), 42, 1967.

16. Tinker, B. L., L. J. Ronsivalli, and J. W. Salvin. Suitability of flexible plastics or packaging materials for radiopasteurized seafoods. Food Technology, 122 (1362), October 1966.

17. Payne, G. O., Jr., C. J. Spiegl, and F. E. Long. Study of extractable substances and microbial penetration of polymeric packaging materials to develop flexible plastic containers for radiation sterilized foods. U. S. Army Natick Laboratories, Technical Report 69-57-FL, January 1969 (AD 685831).*

18. Maunder, D. T. and J. F. Folinazzo. Bio-test method for determining integrity of flexible packages of shelf-stable foods. Food Technology 22, (615), 81, 1968.

19. Morgan, B. H., F. E. Long, and J. H. Bock. Problems in assuring sterility in thermally preserved flexibly packaged foods. Activities Report, Research and Development Associates, 13, (4), 218, 1961.

20. Pflug, I. J., J. H. Bork, and F. E. Long. Sterilization of foods in flexible packages. Food Technology 17, (9), 87, 1963.

21. Wornick, R., M. Karel, and B. E. Proctor. Heat penetration into plastic packages for heat-processed foods. Packaging Engineering 5, (7), 33, 1960.

22. Pflug, I. J. Evaluation of heating media for producing shelf stable food in flexible packages. U. S. Army Natick Laboratories. Final Report -- Phase I, Contract No. DA 19-129-AMC-145(N). Michigan State University, 1964 (AD 462851).*

23. Pflug, I. J. and C. Borrero. Heating media for processing foods in flexible packages. U. S. Army Natick Laboratories, Phase II, Technical Report 67-47-GP, May 1967 (AD 653596).*

24. Robertson, W. F. and C. F. Schmidt. Inoculated pack in 6 x 8 x 3/4" flexible pouches of pear with brine and peas with butter sauce. Unpublished Report, Continental Can Co., May 1970.

25. Lawler, F. K. New sterilizer made in France. Food Engineering, 73, July 1967.

26. Turtle, B. I. and M. G. Alderson. Sterilizable aluminum foil food packs. Packaging, 71, July 1968.

27. Goldfarb, P. L. Pouch for low-acid foods. Modern Packaging, 70, December 1970.

28. Whiting, C. S. Bacteriology of wieners, beef steak and BBQ beef for Contract No. DA-19-129-AMC-573(N). Unpublished Oscar Mayer Report, Project 2814-823-03-03, December 1965.

29. Whiting, C. S. Sterility checks on products for Army Contract No. DA-19-129-AMC-884(N). Unpublished Oscar Mayer Report, Project 2814-844-01-02, June 1966.

30. Fiori, F. and S. Fishman. Abuse tests on flexible packages of thermoprocessed foods. Unpublished NLABS data, August 1967.

31. Lechtur, C. P. Review of defect creation techniques on packages of thermally processed foods. Unpublished NLABS data, August 1968.

32. Glazer, R., K. Zimmerman, and E. Cahill. Autodetection of potential microbial hazard in military subsistence thermoprocessed in flexible containers. Report of Contract No. DAAG 17-68-C-0173, ASD Report No. 3462, Litton Systems, Inc. November 1970.

33. Spencer, W. T. and H. A. Bodman. Nondestructive testing of packages of thermoprocessed foods. Report of Contract No. DAAG 17-69-C-0013, Phase II, AVCO Corporation, December 1970.

34. Lampi, R. A. The reliability of flexible packages. Activities Report, Research and Development Associates, 20, (2), 140, 1968.

35. Peryam, D. R. and N. F. Girardot. Advanced taste test method. Food Engineering 24, 58, 1952.

36. Burt, T. B. Engineer test of flexible packages for heat-processed foods -- peaches. Technical Report T-163, FEA 6001, July 1960.*

37. Burt, T. B. Engineering test of flexible packages for heat processed food -- blueberries and whole cranberry sauce. Technical Report T-199, FEA 61046, June 1961.*

38. Burt, T. B. Engineering test of packaging, flexible, for heat-processed beefsteak. Report of USATECOM Project No. 7K-3173-01, April 1963.*

39. Brugh, J. F. Engineer design test of flexible packages for heat-processed foods -- fruitcake and date pudding. Report of USATECOM Project No. 7-3-0173-02K, August 1964.*

40. Brugh, J. F. Engineer design test of flexible packages for heat-processed foods -- beans, green; corn, whole kernel; chicken a la king. Report of USATECOM Project No. 7-3-0173-03K, September, 1964.*

41. Burt, T. B. Engineering test of meal, ready-to-eat, individual. Report of USATECOM Project No. 8-3-7400-04K, May 1964.*

42. Duxbury, D. D. Automated system for thermoprocessed foods in flexible packages. Report of Contract No. DAAG 17-69-C-0160. Phase I, Swift & Company, July 1970.

43. Schulz, G. L. and R. Mansur. Sealing through contaminated pouch surfaces. U. S. Army Natick Laboratories, Technical Report 69-76-GP, May 1969 (AD 692864).*

44. Lampi, R. A., F. Fiori, and K. H. Hu. The use of infrared radiometric microscope in the nondestructive determination of flexible package seal defects. U. S. Army Natick Laboratories, Technical Report 68-60-GP, May 1968 (AD 676152).*

45. Troy, V. S. and J. F. Folinazzo. Handling filled cans carefully can cut your spoilage rate. Package Engineering 7, (9), 53, 1962.

*These documents are generally available from the following agency:

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